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Post-concussion recovery in children and adolescents: A narrative review

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Abstract

Objectives: To determine if current evidence supports a slower recovery from concussion in children and adolescents when compared to adults, and to assess current management guidelines in view of this evidence.
Design: Narrative review.
Methods: We examined key recent research studies relating to the question "do children take longer to recover from concussion than adults?" Concussion management strategies and a sample of guidelines from different organisations were analysed in view of the current literature.
Results: Recovery has been defined as return to baseline on self-reported concussion symptoms or measures of cognitive deficit. Some studies have compared measures of recovery between children and young adults, and a number of cross-sectional studies have compared groups of children of different ages. The findings varied; however, most studies suggested that children may take longer to recover than adults. Age-related differences have been considered when designing guidelines for the management of concussion.
Conclusions: In view of the differences in time to recovery in children, this review supports the use of more conservative concussion management guidelines in children than in adults.

Keywords

Brain concussion, mild traumatic brain injury, head injury, children, youth sports, clinical management

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Introduction

Concussion is a subset of mild traumatic brain injury and represents a complex pathophysiological process affecting the brain, induced by biomechanical forces. It is usually characterised by a transient impairment of neurological function. Concussion is often caused by a direct blow to the head but can be caused by a blow to any part of the body, where that force is then transmitted to the head.[1,2] While concussion is a serious injury at any age, there are particular issues that need to be taken into account when considering concussion in children. Recovery from a concussion seems to progress differently in children compared to adults, supporting the requirement for specific management protocols for children. Except for those children of older age and advanced maturity (physical, mental and emotional development), most children are usually under the supervision of an adult (parent, teacher, coach, etc.) and are not able to make their own medical decisions. Care of concussed children is often dependent on their doctor, parent, guardian, coach or teacher having appropriate knowledge. It is crucial that accurate guidelines are available to the supervisors of children, to inform management and return to sport decisions following concussion.

Methods

Electronic databases (PubMed, SPORTDiscus, CINAHL and MEDLINE) were searched for articles using the following constructs: concuss* AND (symptom* OR recover* OR resol*) AND (age OR child*),

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published in English up to May 2017. Articles were selected by reading abstracts and the full article if required. Further articles were derived from the references of the retrieved articles and systematic reviews.

Background

Concussion occurs in a wide range of children's sport and recreational activities[3] and is an issue of growing concern for all stakeholders involved in children's sport. It is estimated that children from the USA aged up to 18 years suffer between 1.1 and 1.9 million concussions per year in the context of sport and recreation.[4] It must be noted that sport-related concussion rates may actually be higher due to under-reporting by athletes, parents or coaches,[5] and that only 12% of children's concussions present to the emergency department.[6] The high participation rates of children in sport and the increased social awareness of the potential neurological consequences of concussion have made this a primary area of focus for injury research.

Epidemiological research has produced inconsistent results when examining age as a potential risk factor for concussion. Studies based on reporting by athletic trainers in the USA have indicated both lower[7] and higher[8] sports-related concussion rates in high-school than in college athletes. Two recent studies described concussion incidence across sports as 0.14–9.21 per 10,000 athletic exposures (AEs) in high-school athletes[9] and 0.9–8.9 per 10,000 AEs in college athletes.[10] Incidence in younger children, aged 8 to 12 years, of concussions reported by coaches, parents and researchers which were subsequently confirmed by medical professionals, was not different from that in older children and adults.[11] A screening of three different populations of rugby league players at a national tournament in South Africa indicated that the highest concussion rate occurred in players in the under-16 group (ages 14–16), while the under-13 (ages 12–13) and under-18 (ages 17–18) groups showed similar rates.[12] The evidence for an association between specific age groups and concussion risk is therefore inconclusive.[13]

Age may affect concussion risk through a number of external or physical factors. External factors like lower skill levels have previously been used to explain higher concussion rates in children. Alternatively, higher speed, strength and size have been suggested to justify higher incidence in adults.[7] However, there is no evidence supporting an association between any of these factors and injury risk. Potential physical and physiological risk factors associated with younger age include different head size and neck strength, thinner skull, greater brain water content, a lower degree of myelination, a developing vasculature or a different skull shape.[14] Little is known about the kinematics of acceleration on children's brains,[15] but studies have shown an inverse effect of head mass on linear acceleration, which could provide a mechanism for higher concussion incidence in children.[16] Neck strength, which is significantly reduced in young athletes in comparison to adult athletes,[17] may potentially be associated with concussion.[18] Finally, physiological differences between child and adult brains may explain differences in concussion severity,[19] but this hypothesis cannot be tested until we have a more complete understanding of the pathophysiology of concussion.

The topic of age-related differences in concussion recovery has been the focus of recent systematic reviews.[20,21] The underlying conclusion is that the available literature is unable to provide solid evidence for translation. Meanwhile, sports organisations have been compelled to interpret this inconclusive evidence and translate it into guidelines. As we show here, their interpretation of the evidence varies greatly. This review highlights the main research outcomes, identifies the gap between evidence and guidelines and attempts to provide an avenue for future interpretation efforts for the development of guidelines.

Children and adolescents may experience delayed recovery from concussion in comparison to adults

Early studies indicated that the majority of adults suffering from concussion recover fully without intervention within 7 to 10 days.[1] More recently, after changes in management, authors have suggested a time to clinical recovery of 10 to 14 days.[2,22] Children however do not seem to follow the same time frames to recovery as adults. In this regard, a meta-analysis identified 18 as the age at which changes are observed in the recovery process,[21] and more recently the Berlin Consensus Statement has established 18 and under as the age group of athletes that should be considered children.[2] However, the evidence for this decision is unclear given that the associated systematic review admits that the literature has not adequately addressed the question.[20] The most common research design assessing differences between under 18 and 18 or older subjects has compared high-school and college athletes.[21,23,24] These studies generally define recovery as return to baseline or control group levels in self-reported symptoms or cognitive performance. Two studies indicated slower cognitive recovery in the high-school group than in the college group. The first study, by Field et al.,[23] observed persisting deficiencies in neuropsychological performance in a high-school group when a college group had returned to baseline seven days after concussion. In the second study, more severe impairments were reported in high-school

students up to seven days post-concussion in verbal memory and up to two days post-concussion in visual memory.[24] However, none of these studies found any clear differences in self-reported symptoms.[23,24] Conversely, a meta-analysis of six studies reported longer and more variable self-reported symptomatic periods in high-school than in college athletes (15 and 6 days, respectively), but similar times to cognitive recovery (7 and 5 days, respectively).[21]

Research restricted to high-school athletes compared memory function and other neurocognitive measures of concussion in injured subjects and controls. The results indicated that, despite showing acute neurocognitive deficits similar to older athletes, high-school children required a longer recovery period and their memory impairments only resolved 10 days after the injury.[25] Two studies by another research group, evaluating a large number of participants, reported minimal differences between high-school and college athletes, with a mean time to symptomatic recovery of seven days.[26] Even though cognitive recovery was shown to take one to two days longer in the younger group, none of the measures showed significance up to 90 days post-concussion.[27] Similar results were obtained by Makdissi et al.[28] who, when comparing groups aged 16–17 years old and 18 and over, did not find any significant differences in symptomatic recovery or cognitive performance. Researchers have also assessed the effect of age on presence of abnormally prolonged post-concussive symptoms. A recent meta-analysis has suggested that as many as half of the cases presented with alterations in cognitive function three months to one year after concussion, but age below 18 did not have any impact on this rate.[29] The evidence therefore remains controversial; however, the 2017 Berlin Consensus Statement defines expected time frames for normal clinical recovery to be different in adults (10–14 days) and children aged 18 or under (4 weeks).[2] The latter was confirmed by a series of systematic reviews by Davis et al.[20] In view of the evidence, the current uncertainty warrants a more conservative treatment of children after concussion, in the interest of safety, until further evidence proves otherwise.

Very few studies have assessed the resolution of concussion symptoms in children of primary school age (5–12 years).[2] A longitudinal study of children aged 10 to 17 years reported a rate of recovery comparatively slower to most studies conducted in adolescents and adults with as many as half the children under observation experiencing neurocognitive deficits relative to preinjury baseline by day 10 post-injury.[30] Another research group followed patients aged 10 to 17 and reported a median recovery time of 17 days, with over one in four patients taking longer than four weeks to recover. Age within this group, however, was not associated with time to recovery.[31] Babcock et al.[32] reported less incidence of persistent symptoms three months after the injury in children aged 5 to 10 than in those aged 11 to 18 after concussion of diverse aetiology including sport. Another study conducted on 11- to 22-year-old patients with concussions of diverse aetiology revealed age 13 and over as a significant predictor of persistent symptoms.[33] A descriptive study, based on reports by athletic trainers at football training and games, showed that high-school athletes reported significantly more symptoms than younger athletes, and that both groups had a higher likelihood of return to play later than 30 days after injury than college athletes.[34] Likewise, elementary school students required a significantly shorter recovery period from sports-related concussion than high-school[35] or high-school and college students.[36] More recently, in a sample of children aged 2 to 12 who had suffered concussions of diverse mechanisms, older age at injury predicted persistence of symptoms beyond one month[37]; however, in another sample of children aged 6 to 12, younger age was shown to be a risk factor for prolonged recovery.[38] In athletes aged 7 to 27, no independent effect of age was found on symptom duration.[39] In the case of those with more severe mild traumatic brain injuries presenting to the emergency department, no independent effect of age could be shown for discharge recommendations across the range from 0 to 18 years of age.[40] Some of these studies suggest a non-linear effect of age on persistence of symptoms with a possible implication that younger children and adults recover faster than adolescents,[20] but comparison is challenging when age limits for each category vary between studies. The differences may reflect the intrinsic differences between the child and adolescent brain[41] or result from concussions being less serious in younger children than in adolescents or adults. Alternatively, they may result from measurement systems that inadvertently favour differences between the different age groups or are not sensitive enough for younger children. Without a thorough understanding of brain development and its impact on concussion severity, this observation remains anecdotal.

Implications for concussion management and return to sport policies – Should children be considered different from adults?

The 2017 Berlin Consensus Statement supports removing athletes from sport or high-intensity cognitive activity in the acute period of one to two days post-injury,[2] which reflects initial recovery in motor coordination and balance.[26,42] The need to remove patients from activity has been supported by two recent prospective studies. An observational study of children and

adolescents between 11 and 19 years of age found an association between the time lapse from injury to the beginning of physical and cognitive rest and the time taken to recovery, which was defined as academic activity at pre-concussion levels.[43] Another study compared a group of athletes (aged 12–19) who were immediately removed from sport and training activities at the time of enrolment in the study, with a second group who continued to play after sustaining a concussion and were only removed from sport days later. This study defined recovery as medical clearance to return to full-contact sport. Those athletes who continued playing sport after the injury took twice as long to recover than those who were immediately removed from sport.[44] These two studies support the benefits of rest in the acute phase post-concussion. When assessing the requirement for rest and the impact of activity (prescribed or voluntary) on concussion recovery beyond the first one to two days, three recent systematic reviews[20,45,46] concluded that there is no solid evidence to rule out moderate intensity activity beyond that time period. In addition, the authors question long periods

Table 1. Example of current guidelines for return to sport after concussion, their stated definitions and minimum periods to return to sport for children and adults.

Guidelines	Year released	Asymptomatic rest period (minimum)		Return to sport (minimum)		Definition of rest	Definition of child
		Children	Adults	Children	Adults		
Football Federation Australia[58]	2013	14 days	14 days	19 days	19 days	Complete physical and cognitive rest	No specific guidelines for children
Ontario Neurotrauma Foundation[60]	2013	7 days	1 day	12 days	6 days	Physical and cognitive rest	Age under 18
World Rugby[56]	2015	Longer than 1 day	1 day	14 days after end of symptoms	6 days	Complete body and brain rest, avoiding physical (running, cycling, swimming, physical work, etc.) and cognitive (school work, homework, reading, television, etc.) activities	?
Football Association of Great Britain[54]	2015	14 days	14 days	23 days	19 days	Complete body and brain rest, avoiding physical (running, cycling, swimming, physical work, etc.) and cognitive (school work, homework, reading, television, etc.) activities	Age 19 and under
Sports Scotland[55]	2015	14 days	7 days	23 days	12 days	Complete body and brain rest, avoiding physical (running, cycling, swimming, physical work, etc.) and cognitive (school work, homework, reading, television, etc.) activities	Age 18 and under
Sports Concussion South Africa[57]	2016	2 days	1 day	7 days	6 days	Complete rest from physical activity	Under 13
Australian Institute of Sport/Australian Medical Association[59]	2016	2 days	2 days	15 days	7 days	Deliberate physical and cognitive rest - time off school or work and deliberate rest from cognitive activity	Age 18 and under

of strict rest,[45] and provide some evidence in favour of controlled submaximal exercise programmes,[46] which should be supervised by qualified personnel.[20]

An additional challenge in the management of sports-related concussion is clearance to return to sport.[20] It is recommended that athletes of all age groups do not return to sport while recovering from concussion because cognitive impairments may impair their physical performance. Accordingly, evidence shows that children in the post-concussion period are three times more likely to sustain another concussion than those without a history of concussion.[47,48] This increased risk is particularly relevant because recurrent concussions may be associated with worse symptoms and delayed recovery.[49] In adults, the rate of lower limb musculoskeletal injury in the 90-day period following return to sport after concussion has been reported as nearly 2.5 times higher than in controls,[50] which the authors suggest may be a consequence of long-term detrimental effects of concussion on neuromotor ability. The increased risk of injury in the post-concussive period, together with the potential association of repeated concussions with injury severity or delayed recovery, supports careful consideration in the design of return to sport protocols.

In children and adults, return to sport is only recommended when the athlete is free of symptoms and assessment test scores have returned to baseline.[51] The Berlin Consensus Statement recommends no same day return to sport, a brief period of physical and cognitive rest (1–2 days), a monitored protocol of symptom-limited activity until symptoms have resolved and a graduated programme of activity prior to clearance to return to sport.[2] The Consensus Statement recommends that child and adolescent guidelines refer to individuals aged 18 or under.[2,20] Based on a series of systematic reviews comparing different aspects of concussion diagnosis and management in children,[20] it proposes a typical recovery period of four weeks in children (as opposed to 10–14 days in adults) but it does not state the need for child-specific management strategies.[2,20] However, the need for a child-specific protocol has previously been established.[52,53] Based on the 2013 Zurich Consensus Statement,[1] a number of organisations throughout the world have developed guidelines to facilitate post-concussion management by medical practitioners (Table 1).[54–60] They offer different recommendations for the management of adults and children. The minimum period recommended from concussion to return to contact sport varies between 7 and 23 days for children and between 6 and 19 days for adults. The cut-off age to consider a patient as a child varies, but most suggest 18 or 19 years old.[54–60]

The definition of "rest post-concussion" is similar in the majority of these guidelines, and most of them specifically recommend protocols for children including longer periods of complete rest than adults.[54–57,59,60] In the belief that complete rest is impossible to achieve, the Australian Institute of Sport (AIS) and Australian Medical Association[59] (AMA) have changed their qualification of rest from "complete" to "deliberate",

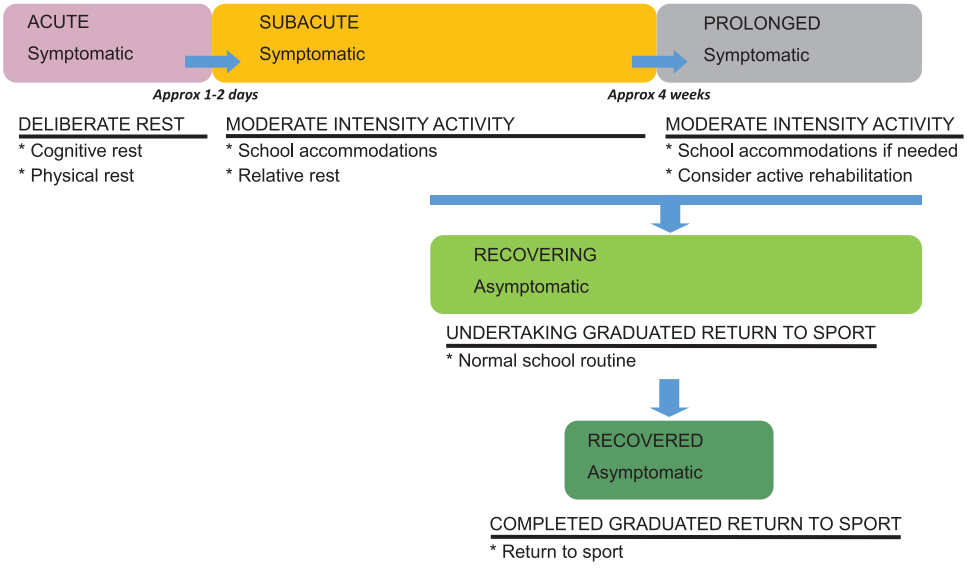

Figure 1. The phases of post-concussion recovery in children and the indications for treatment currently supported by the literature. As post-concussion recovery is highly variable between individuals in duration and magnitude, patients should be monitored and assessed on a case-by-case basis.

an option deemed more realistic for uptake by athletes, doctors and parents, and more achievable. In accordance with the Berlin Consensus Statement, the authors have reviewed and modified the guidelines to include a post-acute period of moderate activity at an intensity that does not exacerbate symptoms, followed by a graduated return-to-sport protocol (Figure 1). While there is no conclusive evidence to inform the minimum period required before return to sport in children, the AIS/AMA position statement has determined that a two-week symptom-free period before return to sport is reasonable and aligned with the available literature. The AIS/AMA position statement errs on the side of caution, given the lack of clear scientific evidence and the need to provide safe advice to the grass-roots sporting community.[53] However, management should be according to the pattern of recovery[53] and individualised clinical judgement will continue to influence management decisions.[2] Concussion research progresses at a fast pace and the synthesis of new studies into clear evidence-based protocols in a timely manner is challenging; however, a major effort is being made to regularly translate research to guidelines for clinical practice.

Conclusions

The evidence for differences in the recovery period from a concussion between children and adults is far from definitive. Eighteen years of age is generally agreed as the point at which there is a shift in the recovery process timeline. While some studies show that children have longer symptom resolution periods than adults but no differences in neurological outcomes, others show differences in neurocognitive recovery but not in reported symptom resolution. Yet another set of studies shows no differences between children and adults in any domain. At present, the balance of studies supports a slower resolution in concussion symptoms in children, and the recent Consensus Statement has reflected this by specifying expected symptomatic time frames as >10–14 days in adults and >4 weeks in children.[2] In light of this, there are grounds for a more conservative treatment of children. However, the evidence around precise return to sport timelines in this population is controversial. Contemporary concussion management guidelines published by a range of organisations recommend variable periods of time between symptom resolution and return to full contact activities, and the current evidence suggests individualised follow-up and recommendations based on clinical judgement. Further research into post-concussion recovery in children and adolescent populations is essential in order to develop informative guidelines for return to sport.

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